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ENCLOSURES FOR FUMIGATING STORED RAISINS

by

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Raisins stored in receiving yards before processing may have acquired some insect infestation during the drying process or while stored temporarily on ranches. In receiving yards also, they may be invaded by insects. Fumigation is a quick and effective method of destroying these incipient insect infestations.

Beginning early in 1954, cooperative studies were made by the Dried Fruit Association Laboratory and the Stored-Product Insects Laboratory to evaluate several types of enclosures which were being used by the raisin industry as covers to permit fumigation of raisins in storage. The results of this study are reported herein.

Methods of Storing Raisin Stocks

Raw-stock, unstemmed raisins received from the growers are stored by packers in picking boxes, sweat boxes, and portable bins. The picking boxes are 24 x 16 x 8 inches and hold about 50 pounds of raisins. Sweat boxes are 39 x 27 x 8 inches and hold about 170 pounds of raisins. Portable bins are 4 x 4 x 4 feet and hold about 1,700 pounds of raisins. The bins have pallet-type bottoms and narrow openings between the boards on all sides.

1/ This is one of the field stations of the Stored-Product Insects Section, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service, U. S. Department of Agriculture.

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Practically all stored raisins are stacked in boxes on cement or black-top floors. Only a small part of the raisin industry uses the older method by which boxes are stacked on 4 x 6-inch foundation timbers above a dirt floor. Sweat boxes are stacked 14 or 16 to a pallet, 2 wide, 1 deep, and 7 or 8 high. Picking boxes are stacked 48 to a pallet, 3 wide, 2 deep, and 8 high. Portable bins observed in these studies were stacked 5 high.

As a rule, raisin stacks are covered with temporary or permanent corrugated iron roofs.

Types of Fumigation Enclosures Studied

The need for immediate fumigation of stored raisins early in 1954, caused industry members to devise various methods of enclosing the stacks with tarpaulins or laminated paper, or to utilize fumigation chambers into which the stocks were moved for treatment. Once a stack was enclosed for fumigation, the cover was usually left in place to retard reinfestation, and to permit refumigation if necessary. The types of temporary enclosures included paper-covered frames, a combination of a "permanent" paper-covered wall and a temporary tarpaulin top, plastic-coated nylon tarpaulins, and balloon-cloth tarpaulins. Permanent chambers of masonite or sheet iron were built later. They ranged in size from 4,000 to 72,000 cubic feet. The stacks that were completely covered with paper, with a temporary corrugated iron roof for protection from rain, and the sheet-iron chamber were tested in 1955; the other types were fumigated in 1954. Details of construction are given later in this paper.

Paper-covered stacks:

In preparing a stack for covering with paper (fig. 1) the stack was framed vertically on the sides with 1 x 4-inch lumber, usually nailed to the boxes of raisins. The framing supplied a flat backing for the paper strips and was carried over the top of the stack. Two types of reinforced asphalt-laminated paper were used, one reinforced with glass threads and the other with sisal fibers. The paper came in 6- and 8-foot widths. Since the paper tended to shrink on weathering, allowance for the shrinkage was made by placing the framing strips 5 feet on centers when 6-foot sheets were used, and 7 feet on centers when 8-foot sheets were used.

The paper strips were stapled at intervals to hold them in place. They were then battened down with lengths of lath butted together and nailed at 6-inch intervals. When laths were placed close to the edges of the paper, wandering raisin moth larvae could not find hibernation quarters under the overlap. The paper strips going over the stack were made long enough to allow for vertical shrinkage plus 10- to 12-inch ground laps at the bottom on each side. The paper strips were sealed to the cement or black-top floor with loose, moist soil or sand which extended about 6 inches up the outside of the paper and several inches beyond the paper ground lap. Figure 2 illustrates the same type of covering applied to a raisin stack built under a permanent corrugated iron roof.

Paper-walled and tarpaulin-roofed stacks:

As shown in figure 3, the walls of this type were covered with fibre-reinforced paper in the same manner as the paper-covered stacks. However, in this case the stacks were roofed with corrugated iron to provide protection from rain. During fumigation the roof was covered with a plastic tarpaulin, usually battened to a horizontal framing strip that had been placed around the stack under the eaves. All exposed metal edges of the roof were covered with 1 x 8-inch or 1 x 10-inch boards to prevent rips in the tarpaulin top. The paper walls were extended up to and usually over the eaves where they were battened in place. After fumigation, the plastic cover was moved to another stack.

Paper-covered stacks with sheet-iron roofs:

A row of stacks of this type is illustrated by figure 4. Construction was as follows: The boxes of raisins were stacked in the usual manner with about a ton of fruit on a pallet. Two stacks, each 6 pallets wide, 13 long, and 3 high, were tested. There were about 234 tons of fruit in each stack and the enclosed space was 19,100 cubic feet.

A temporary gable roof was supported above the flat-topped stack of boxes by piers of graduated heights. The roof supports (piers) consisted of picking boxes cleated together. They were placed about 6 feet apart, in rows lengthwise of the stacks. A piece of 2 x 4-inch lumber was nailed to the top of each row of supports. The tallest piers were placed at the center of the stack and piers of graduated heights were built from the peak to the eaves. The number of rows of supports depended on the width of the covering paper and the width of the stack.

A piece of 1 x 4-inch lumber was nailed along the top of each wall and vertical framing was placed between it and the ground, 7 to 7¼ feet apart on centers when the covering paper was 8 feet wide. The walls were covered in the usual manner, with paper extending from the framing member at the top to the ground.

In covering the roof, pieces of paper were cut long enough to reach lengthwise of the stack between the frames at the top of each end. The bottom piece of paper was battened to the horizontal framing at the top of the side, and the other edge was fastened to a longitudinal 2 x 4. This process was continued until enough paper was in place to take a course of corrugated sheet iron. Then a section of sheet iron was put on. This was repeated until the roof was covered, the roofing crews using the sheet iron as a working platform. The paper was spaced on the roof so that there was no joint at the peak. In this way a practically gas-tight paper roof, protected by a sheet iron roof, was constructed.

Plastic-coated nylon tarpaulins:

Six plastic-coated nylon tarpaulins were used to cover a 22,000-cubic-foot stack (fig. 5). The tarpaulins were fastened together with 3-foot rolled overlaps held in place with clamps. Dirt was used to seal the bottom of the tarpaulins to the base. Because the tarpaulins were old and full of pin holes, the dosages of fumigant were increased to compensate for leakage.

Balloon-cloth tarpaulins:

Tarpaulins made of barrage-balloon cloth were used to cover the stacks in two experiments. Three tarpaulins were used to cover the stack in one test: A large one to cover the top and two sides and smaller ones to cover the ends. The adjoining edges of the tarpaulins were fastened tightly together by rolling. They were held in place with clamps at the corners and sand bags on the roof. In the second fumigation a box-type tarpaulin (fig. 6) was tested. It was folded, placed on the roof, then unrolled and the sides dropped to the ground. In both tests the tarpaulins were sealed at the base with dirt. In the first test leaks were discovered at the ground seal. The cloth was stiff and did not lie smoothly on the cement foundation. The trouble was corrected in the second test by using a thin layer of dirt on the cement base, carefully smoothing the cloth over the dirt bed, and placing a dirt seal on the ground lap of the tarpaulin.

Plywood-lined fumigation chamber:

Three fumigations were conducted in a well constructed room made of plywood (fig. 7), which was at least 10 years old. It was built on a cement slab and sealed under the sills and at all joints with mastic. The room had been well maintained and was in excellent condition. Only small leaks were found except around the doors, which were heavy and hung from the top. The leaks were stopped by sealing the door joints with tape before fumigation.

Masonite-lined fumigation chamber:

The masonite panelwood fumigation rooms tested (fig. 8) were new and unpainted. Not enough mastic had been used at the joints to make good seals. Each room had an 18-inch cement sill to which the wood sills were bolted. There was no mastic between the sills but the wall panels were brought down on the cement 3 or 4 inches below the wood sills and a heavy bead of mastic was run along the cement against the bottom of the wall panel. Mastic was not applied to the studding. Instead, a mastic bead was run around the edge of the wall panels before they were nailed in place. Surplus mastic that squeezed out at the edges of panels was carefully wiped off so that the inside of the room had a neat appearance. Shrinkage of the panelwood tended to open the mastic joints, and leaks were numerous.

Figure 9 shows the type of panelwood doors built for 3 masonite rooms that were sheathed on the outside with corrugated iron. The doors are suspended by long hangers from an overhead track. This construction permits the door to hang away from the building when not closed, allowing the operator to move it without contact with the rubber door gaskets. Screw fasteners press the door against the gaskets. The bottom of the door is sealed with sand during fumigation.

In figure 10 a large raisin storage room made of masonite is shown. The masonite has been coated with aluminum paint to seal the panelwood and reflect heat.

Sheet-iron fumigation chamber:

This building, of a new type of construction, has 4 outside walls, is divided into 3 units by 2 interior walls, and has a gable roof over each unit. There is no communication between units. The sills, laid down over adequate amounts of mastic to provide a tight gas seal, are bolted to the cement slab floor. The building frame, corner posts, intermediate studding, plates, and girders were erected on this base. More support members were used than in a standard sheet iron building in order to reduce expansion and contraction.

The sills and plates have soft neoprene gaskets in grooves on the top and bottom. The ends, top, and bottom of the corrugated iron wall strips rest firmly on these gaskets. Inside the corners there are solid angle brackets for gasket material. The edges of the walls and roof strips are sealed by these gaskets, and similar brackets and gaskets are placed at the peak of the roof. In addition, a cap is fitted over the outside of the roof peak. The edges of each covering sheet of corrugated iron carry a patented mastic bead against which the adjoining sheets are forced tightly together with metal screws.

The door in each unit, about 8 feet square, is hinged on one side. It is framed with heavy angle iron and covered in the same manner as the walls of the unit. The doors are well gasketed on 3 sides and during fumigations are sealed at the bottom with loose sand. Ventilating doors are installed above the eaves at either end of the chamber.

Each unit of the building is supplied with gas application equipment which consists of a 3/4-inch pipe entering near the peak of one end and extending to the center of the room. The fumigant is delivered toward the sides of the room through a T.

Figure 11 shows the construction of the door. This type of corrugated iron is known as box-break sheet or deep-square corrugated.

Fumigation Procedure

Methyl bromide was in common use by the industry and was used in all evaluation studies. It was volatilized before introduction, in all tests except one, by passing it through a 25-foot coil of ½-inch (outside diameter) copper tubing submerged in water heated to 200-212° F. The volatilized gas was conducted to the enclosure through a length of 3/4-inch plastic tubing.

In the fumigation of paper- or tarpaulin-covered stacks the fumigant was applied by inserting the tube through the covering and releasing the gas at one or more points as dictated by the size and shape of the stack. As soon as the dosage had been introduced, the tube was removed and the hole sealed with tape. The plywood- and masonite-lined chambers and the corrugated iron room were supplied with permanent fumigant pipe lines which discharged near the ceiling.

In the tighter enclosures the dosage rate was 1 or 1½ pounds per 1,000 cubic feet. In the enclosure covered by the old plastic nylon tarpaulin, the rate was increased to 2¼ pounds. No forced circulation was used, but provision was made for free passage of gas entirely around the load by leaving a head space above the load. All the stacks were built on pallets which provided free space at the floor level.

After the fumigant was applied, a careful search for leaks was made by using a halide leak detector. Any leaks found were eliminated if possible. Poorly fitted doors, missing mastic in cracks and joints, and poorly laid dirt seals at the base of stacks were the commonest causes of leakage.

Gas sampling tubes were placed at the top, middle, and bottom levels in each enclosure under test, and samples were taken after approximately 2, 6, and 24 hours. The concentrations were determined by a thermal-conductivity gas analyzer in one test and by chemical analysis by the Volhard method in the others.

Insect samples were included in most tests: 3 samples on the top pallets, 4 on the middle pallets, and 3 on the bottom pallets. Each sample contained 10 Indian-meal moth larvae and 10 flour beetle adults. In 2 tests the insects were in perforated pill boxes buried in the raisins; in 3 fumigations they were in gelatine capsules within perforated probes inserted at the center of portable bins, and in the other tests they were in gelatine capsules within cloth bags buried in the raisins. Mortality counts were made at the end of the fumigation, and any insects not dead upon removal were kept for subsequent observation.

Samples of raisins were also removed from fumigated stocks and examined for insects by sifting.

One set of figures on the effect of weathering on gas retention was obtained by fumigating the same paper-covered stack on May 3 and again on June 30 (table 2).

In one experiment a masonite room was fumigated when empty and later when it was loaded with raisins (table 3).

Results

The efficiency of the various stacks and fumigation chambers in retaining effective concentrations of methyl bromide is shown by the data of tables 1, 2, and 3. In table 1 data are given regarding gas concentrations at intervals of 2, 6, and 24 hours during the initial fumigation of 8 different types of enclosures. In table 2 data are given to show the effect of weathering on the gas-retaining properties of one of the paper-covered stacks. Gas concentrations obtained when the stack was fumigated after weathering for 2 months are compared with those obtained during the initial fumigation. In table 3 gas concentrations obtained during the fumigation of a masonite chamber when empty and when filled with raisins are compared.

After fumigation, all insects exposed in test cages (1,100 Indian-meal moth larvae and 1,300 adult flour beetles) were found to have been killed. Raisins removed from the paper- and tarpaulin-covered stacks fumigated in January were examined by sifting. All insects removed during the sifting operation were found to be dead. Included among the insects were moth larvae, pupae, and adults, larvae of dermestid beetles, and saw-toothed grain beetles.

No living insects were found by sifting boxes of raisins fumigated on February 19 and removed from the stack when it was uncovered and broken down on May 5. This indicated that the stack covering protected the raisins from invading insects during the 3-month storage period following fumigation.

Discussion

All of the enclosures evaluated were efficient in that they were tight enough to retain sufficient fumigant to kill all insects. The room lined with unpainted masonite lost its concentration most rapidly and was the least efficient, but even here 100 percent mortality occurred. It should be noted that 6 ounces or more of fumigant per 1,000 cubic feet were present for the first 6 hours in all enclosures. A paper covering showed some effect of weathering after 2 months, but the gas retention was still sufficient for effective fumigation.

Summary

Laminated paper coverings, paper-walled and tarpaulin-roofed coverings, balloon-cloth tarpaulins, plastic-coated nylon tarpaulins, plywood- or masonite-lined fumigation chambers, and a sheet-iron room were all satisfactory as enclosures for the fumigation of raw-stock raisins in commercial-size lots, in cooperative studies made at Fresno, Calif., by the Dried Fruit Association of California Laboratory and the Stored-Product Insects Laboratory. Concentrations of 6 or more ounces of fumigant per 1,000 cubic feet were retained 6 hours or longer in all enclosures tested, following initial dosages applied at the rate of from 1 to 2-1/4 pounds of methyl bromide per 1,000 cubic feet, and all test insects were killed. One stack covering when left in place protected the raisins from reinfestation during the period from February 19 to May 5.

Table 1.--Average concentrations of methyl bromide present during the course of routine fumigations in the various types of enclosures evaluated

Type of enclosure	Date of fumigation	Range of fruit temperature	Dosage rate per 1000 cubic feet	Concentration of gas per 1000 cubic feet after			Percentage of original dosage remaining after		
				2 hours	6 hours	24 hours	2 hours	6 hours	24 hours
	1954	°F.	Ounces	Ounces	Ounces	Ounces	Percent	Percent	Percent
1. Paper-covered stacks. . .	1/20	45-52	24	17.7	--	18.0	73.8	--	75.0
	3/30	53-54	16	10.4	8.0	6.8	65.0	50.0	42.3
	5/3	--	16	14.5	12.3	8.3	90.6	76.9	51.9
	6/30	81-82	16	11.7	9.3	6.6	73.1	58.1	41.3
2. Paper-walled stacks with plastic tarpaulin roof.	2/19	49-50	16	11.2	10.2	6.8	70.0	63.8	42.5
3. Plastic-coated nylon tarpaulin-covered stacks.	1/27	46-50	36	17.5 1/	--	12.0 1/	48.6 1/	--	33.3 1/
				17.0	--	12.2	47.0	--	33.9
4. Balloon cloth tarpaulin-covered stacks.	3/22	51-51	24	--	--	10.3	--	--	42.9
	4/13	62-65	16	12.1	--	6.5	75.6	--	40.6
5. Plywood fumigation room. . .	2/25	56-57	16	--	--	10.7	--	--	66.9
	3/2	57-61	16	14.9	--	9.4	93.1	--	58.8
	3/16	56-57	16	16.3	--	9.5	101.9	--	59.4
6. Masonite panelwood fumigation room (unpainted).	5/10	--	16	--	9.0	2.0	--	56.3	12.5
	5/19	77-78	16	9.3	6.0	1.9	58.1	37.5	11.9
	5/25	--	16	14.8	10.8	3.4	92.5	67.5	21.3
	6/2	73-76	16	8.9	6.8	1.4	55.6	42.5	8.8

--Continued

Table 1.--(Continued.)

Type of enclosure	Date of fumigation	Range of fruit temperature	Dosage rate per 1000 cubic feet	Concentration of gas per 1000 cubic feet after			Percentage of original dosage remaining after		
				2 hours	6 hours	24 hours	2 hours	6 hours	24 hours
	1955	°F.	Ounces	Ounces	Ounces	Ounces	Percent	Percent	Percent
7. Corrugated iron room	11/15	54	16	--	13.1	7.7	--	81.2	48.1
8. Paper-covered stack with temporary corrugated iron roof.	12/19	52	24	--	13.5	9.9	--	56.5	41.3
	1956								
	1/3	52	16	--	--	7.2	--	--	45.0

1/ Analysis made with a thermal-conductivity gas analyzer.

Table 2.--Concentrations of methyl bromide present in a paper-covered, 17,000-cubic-foot stack of raisins following fumigation on May 3, 1954, with a dosage rate of 16 ounces per 1000 cubic feet, and refumigation on June 30

Exposure period	Concentration of gas per 1000 cubic feet		Percent of original dosage present	
	May 3 fumigation	June 30 fumigation	May 3 fumigation	June 30 fumigation
Hours	Ounces	Ounces	Percent	Percent
2	14.6	11.7	91.3	73.1
6	12.3	9.3	76.9	58.1
24	8.3	6.6	51.9	41.2
48	6.7	4.9	41.9	30.6
72	5.8	4.2	36.3	26.3

Table 3.--Concentration of methyl bromide present in a 29,000-cubic-foot masonite fumigation chamber following fumigations with a dosage rate of 16 ounces per 1000 cubic feet when empty, and when loaded with 325 tons of raisins

Exposure period	Concentration of gas per 1000 cubic feet		Percent of original dosage present	
	Empty chamber	Loaded chamber	Empty chamber	Loaded chamber
Hours	Ounces	Ounces	Percent	Percent
3	14.8	8.9	92.5	55.6
6	10.8	6.8	67.5	42.5
24	3.4	1.4	21.4	8.8
48	0.7	0.7	4.4	4.4

Figure 1.--Fumigation of raisins in storage with methyl bromide. A type of laminated paper stack cover built in 1954. These raisins were stored in picking boxes.

Figure 2.--Raisin stack built under a permanent corrugated iron roof and covered with laminated paper.

Figure 3.--Raisin stack with walls (but not the roof) covered with laminated paper. The roof was covered with corrugated iron to protect the fruit from rain. During fumigation a tarpaulin was placed over the iron roof and held down by pallets.

Figure 4.--Raisin stacks completely covered with laminated paper and protected from rain by corrugated iron roofs. The strip of paper around the bottom of each stack was applied after a winter of weathering had deteriorated the lower part of the original covering.

Figure 5.--Fumigation of raisins in storage with methyl bromide under plastic-coated tarpaulins.

Figure 6.--Fumigation of raisins in storage with methyl bromide under balloon-cloth tarpaulin built in one piece.

Figure 7.--Plywood fumigation chamber with door hinged at top and operated with a cable and crank. When closed, the sides and top are sealed with tape and the bottom with sand.

Figure 8.--Interior of a fumigation room newly constructed of untempered panelwood, containing raisins stored in sweat boxes. Edges of sheets sealed with hard-drying white mastic. Gas retention can be improved by painting. Ceiling openings are for recessed lights.

Figure 9.--A satisfactory type of door for fumigation rooms. The door is suspended by long hangers from an overhead track and when closed is forced against door-frame gaskets by screw fasteners.

Figure 10.--Large masonite panelwood raisin storage, coated with aluminum paint.

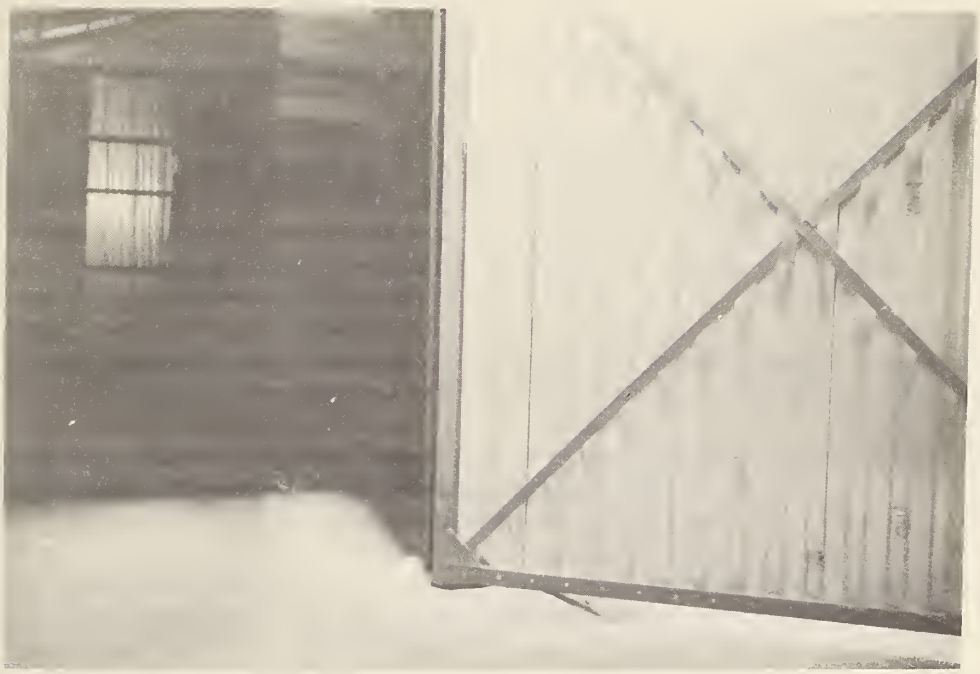

Figure 11.--Door of fumigation chamber made with deep-square corrugated iron. The sheets of iron are fastened together with mastic tape and metal screws.

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